Cryogenic Hydrogen Experiment and Study

Melbourne Energy Institute
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Thermodynamics lab,
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Introduction & Motivation

Hydrogen is attracting major interests as a clean energy carrier and carbon-free fuel. Safety regarding hydrogen storage in liquid form is the focus of large-scale applications. The current experienced-based protocol is out-dated and overconservative, representing a major limiting factor in deploying large-scale hydrogen filling station. Cryogenic hydrogen release is the key method in developing physics-based risk assessment tools of liquid hydrogen storage. With the aid of imaging techniques, such as Schlieren and Mie scattering, and sensory outputs, distribution of concentration and temperature of hydrogen plume can be investigated. The results will provide valuable insight into creating the much-needed risk assessment protocol.

Methodology

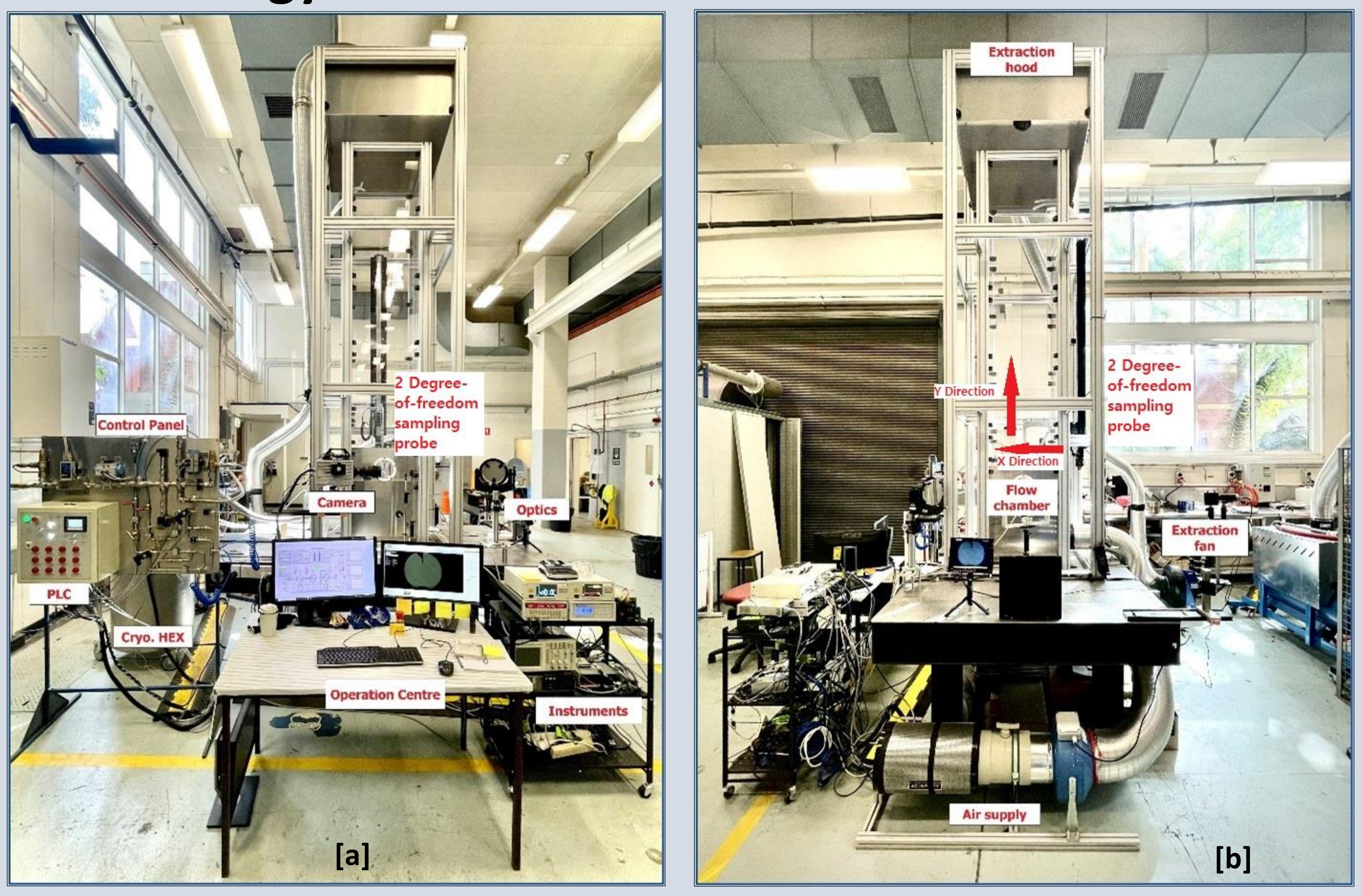

Figure 1: Overall test rig setup (a) front view, (b) side view, 2 degree-of-freedom sampling probe equipped with concentration and temperature sensors shown in both (a) & (b) (University of Melbourne, 2023)

Below is the comprehensive top view of the imaging set up in the laboratory.

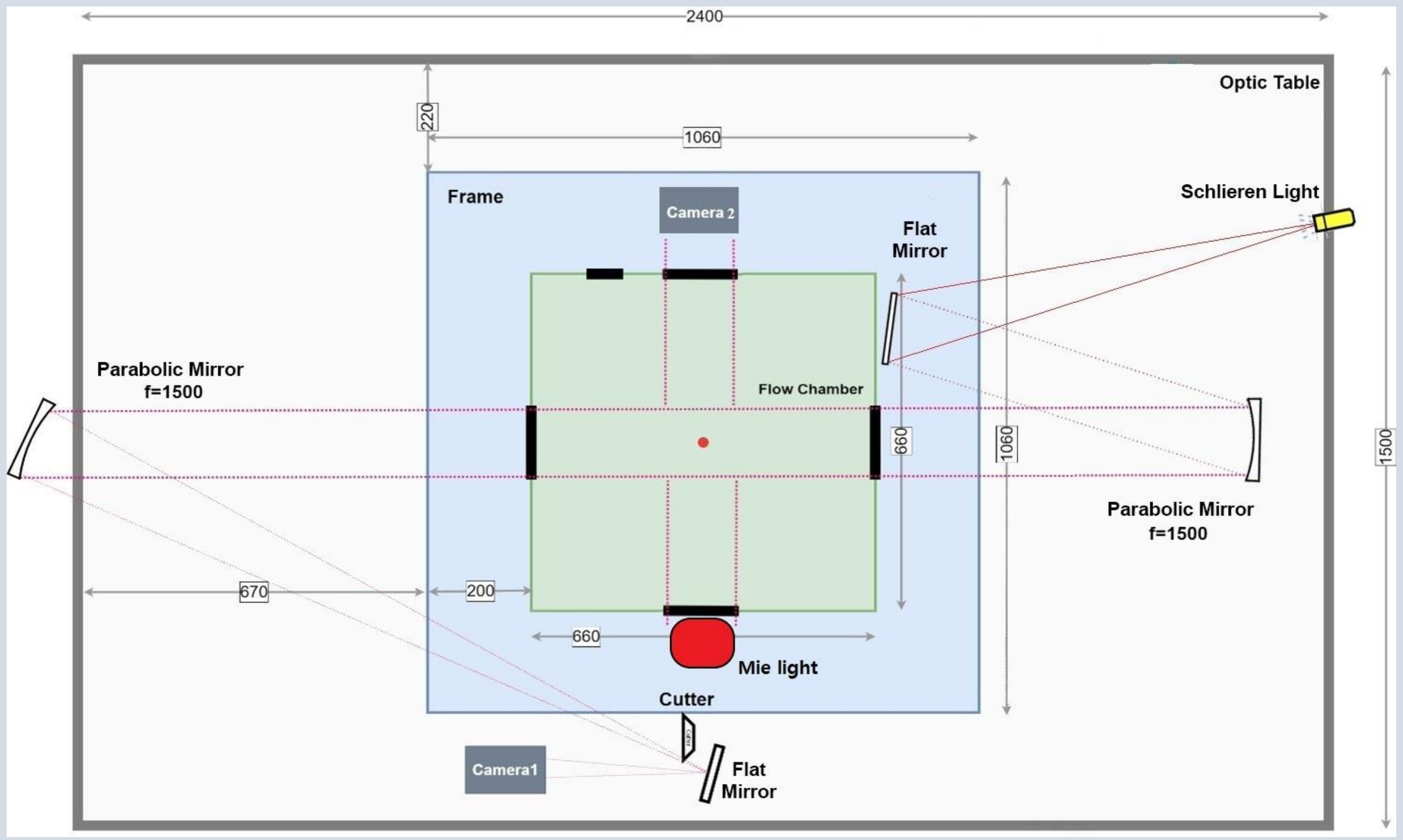

Figure 2: Schlieren and Mie scattering Imaging set up (University of Melbourne, 2023)

Result

The nozzle diameter is 1mm. Three sets of data were acquired under three different conditions, one at 74k, 0.27g/s, 2.9bar, one at 46k, 0.47g/s, 3.9bar, another one at 36k, 0.3g/s, 2.2bar. Due to space limitations, only a selection of comparison among three data outputs and imaging results are shown below.

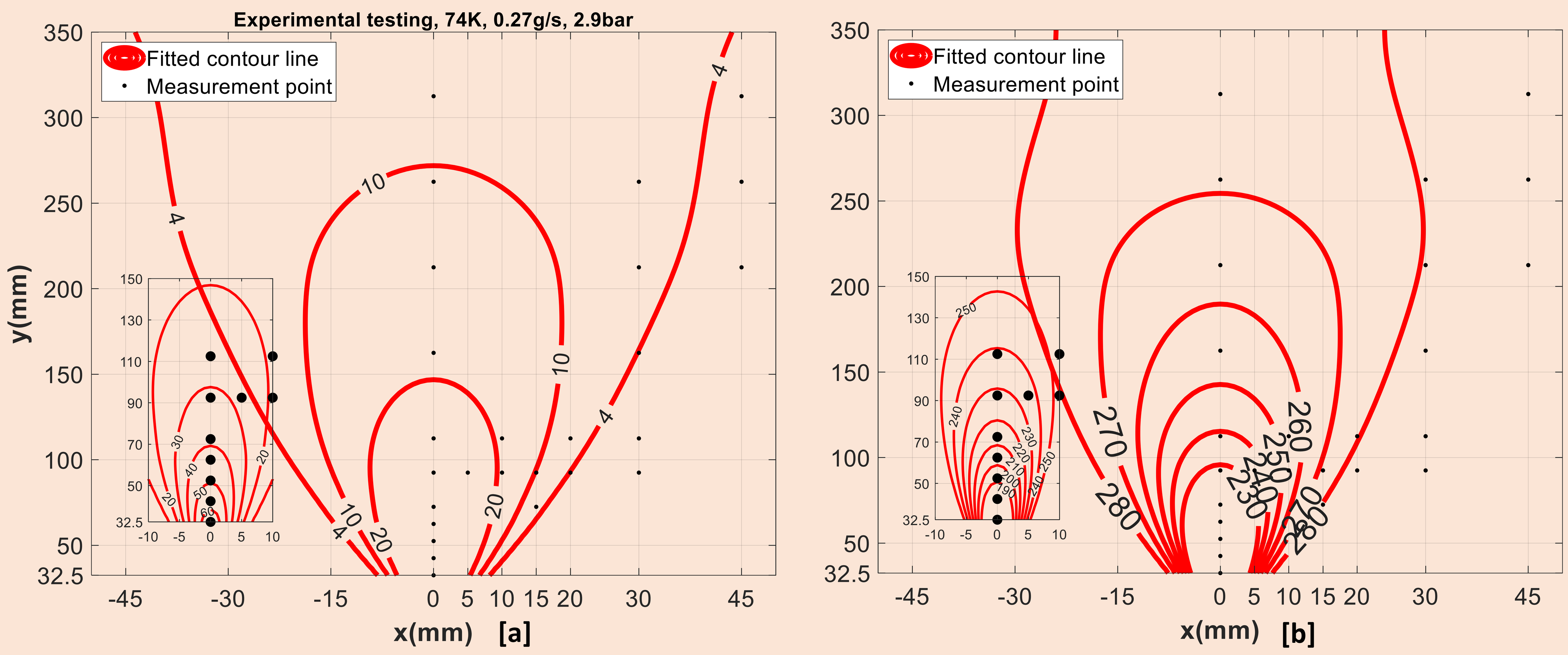

Figure 3: Sensory outputs of plume concentration (a) and temperature (b) at 74k release

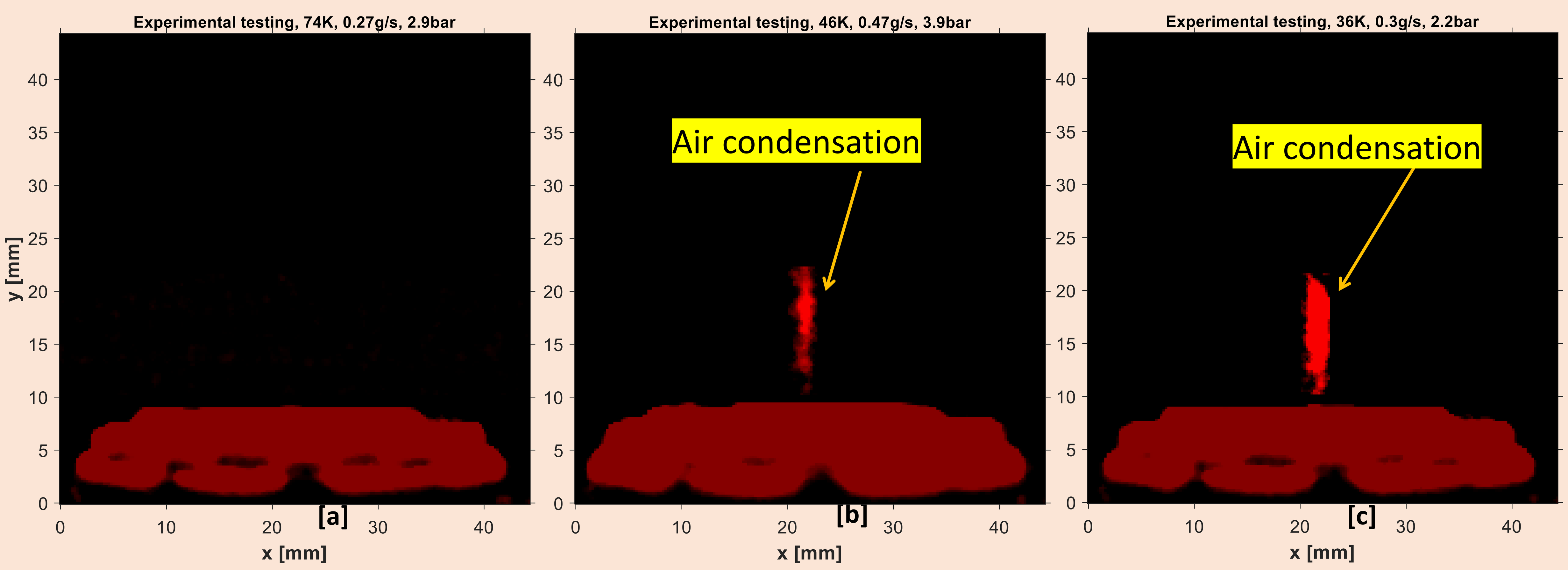

Figure 4: Mie scattering result at 74k release(a), 46k release (b), and 36k release (c), condensation of air components(N2/O2) in (b) & (c)

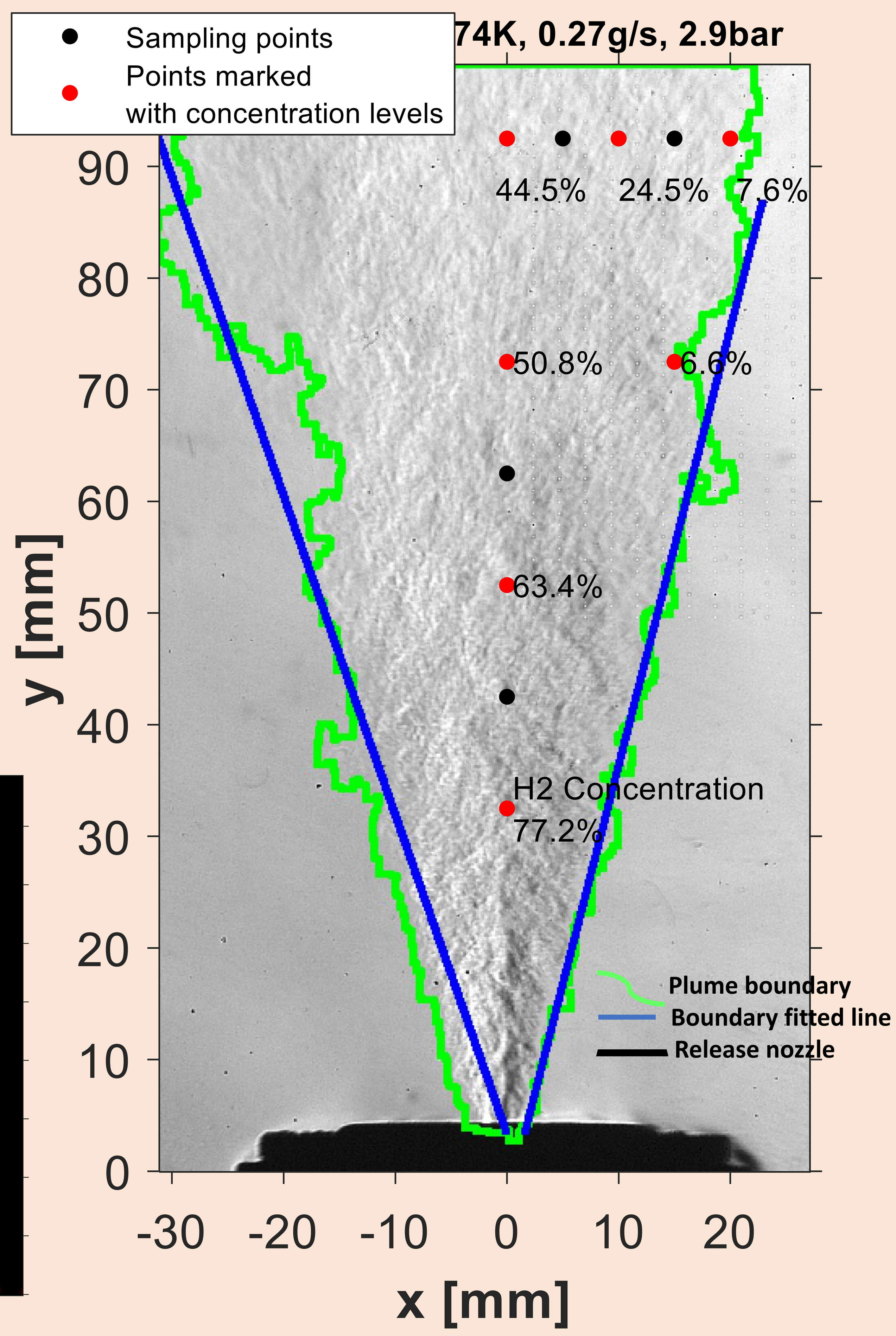

Figure 5: Schlieren results for 74k release, along with experimental sampling points and corresponding concentration levels

Conclusion

The concentration decays while the temperature rises along the centerline and the radial direction for the hydrogen plume released at 74k.

The Schlieren imaging result in figure 5 shows a clear density gradient between the hydrogen plume and the surrounding air.

There is no condensation with 74k release. However, due to low temperature at 46k and 36k, the O2 and N2 are condensed at near nozzle region in figure 5 (b) and (c). The condensation is much stronger at lower temperature (36k). Rain out could happen if we further lower the release temperature to below 20k.

More experiments will be conducted for cryogenic hydrogen releases at even lower temperature and higher pressure to provide more comprehensive data. Calibrated Schlieren will be added to the current Schlieren setup to provide quantifiable data which can be used to corroborate the sensory results.
Air condensation phenomena will also be further investigated to determine its effect on the plume formation.

Contact

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References

University of Melbourne. (2023). Experiments and simulations examining leaks and venting of cryogenic hydrogen. UoM/FFI cryogenic hydrogen research project.

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